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(54) **[Title of the Invention]** Preamplifier Circuit for Photoelectric Conversion

(57) **[Abstract]**

[Object] Relating to a preamplifier circuit for photoelectric conversion used for the input stage or the like of an optical transmitter/receiver in optical telecommunications, the object is to provide a preamplifier circuit that operates stably up to a high transmission bit rate, while ensuring a broad dynamic range.

[Constitution] Formed from a photoelectric conversion element that converts an optical signal into an electric signal, and an inverting amplifier circuit connected to the input terminal and the output terminal, with the converted electric signal as an input signal, and characterized in that said inverting amplifier circuit in constructed in multiple stages, utilizing a plurality of inverting amplifiers, and a variable impedance element is connected to the input terminal and the output terminal of the inverting amplifier of the first stage of said inverting amplifier circuit constructed in multiple stages, and in addition, there is provided an impedance control means that controls the impedance of said variable impedance element in response to an output signal of the inverting amplifier of the first stage of said inverting amplifier circuit constructed in multiple stages, and when the input signal increases, the impedance of said variable impedance element is controlled so that it decreases.

EXAMPLE

[Claims of the Invention]

[Claim 1] Preamplifier circuit for photoelectric conversion, formed from a photoelectric conversion element that converts an optical signal into an electric signal, and an inverting amplifier circuit connected to the input terminal and the output terminal, with the converted electric signal as an input signal, and characterized in that said inverting amplifier circuit in constructed in multiple stages, utilizing a plurality of inverting amplifiers, and a variable impedance element is connected to the input terminal and the output terminal of the inverting amplifier of the first stage of said inverting amplifier circuit constructed in multiple stages, and in addition, there is provided an impedance control means that controls the impedance of said variable impedance element in response to an output signal of the inverting amplifier of the first stage of said inverting amplifier circuit constructed in multiple stages, and when the input signal increases, the impedance of said variable impedance element is controlled so that it decreases.

[Claim 2] A preamplifier circuit for photoelectric conversion of Claim 1, characterized in that the impedance of the variable impedance element is set so that it is infinitely great at the lowest receiving level for the input signal.

[Claim 3] A preamplifier circuit for photoelectric conversion of Claim 2, characterized in that the variable impedance element is formed from MOS-type FET.

[Detailed Description of the Invention]

[0001]

[Industrial Field of the Invention] The present invention relates to a preamplifier circuit for photoelectric conversion used for the input stage or the like of an optical transmitter/receiver in optical telecommunications.

[0002]

[Prior Art] FIG. 5 shows a prior art preamplifier circuit for photoelectric conversion in an optical transmitter/receiver. In FIG. 5, *1* is a photodiode that receives an optical pulse signal and converts it into an input signal current I, *2* is an inverting amplifier circuit that amplifies said input signal current I, and *3* is a negative feedback resistor that is connected to the input terminal and the output terminal of the inverting amplifier circuit *2*.

[0003] The preamplifier circuit for photoelectric conversion of FIG. 5 is called a transistor impedance-type preamplifier circuit, and its output voltage V_{OUT} is given by $V_{OUT} = (I \times R_f)$, where R_f is the resistance of the negative feedback resistor *3*.

[0004] Incidentally, preamplifier circuits for photoelectric conversion that are used in optical telecommunications require a broad dynamic range, since high-speed transmission has to be performed. However, in the case of FIG. 5, when the input signal current I is too large, the output voltage V_{OUT} of the inverting amplifier circuit *2* becomes saturated. As a result, the duty ratio of the output pulse changes, so there is the drawback that the dynamic range cannot be broadened.

[0005] Accordingly, heretofore, a method for solving this problem was employed, wherein saturation of the inverting amplifier circuit was prevented by shunting the input signal current to the negative feedback resistor *3*.

[0006] FIG. 6 shows the circuit structure thereof. In FIG. 6, *1* is a photodiode; *2* is a multistage inverting amplifier circuit formed from three inverting amplifier circuits 2_1 - 2_3; *3* is a negative feedback resistor that is connected to the input terminal and the output terminal of the inverting amplifier circuit *2*; *4* is an N-channel MOS-type FET serving as a variable impedance element for shunting, and is connected to the input terminal and the output terminal of the first-stage inverting amplifier circuit 2_1 of the multistage inverting amplifier circuit; *5* is an automatic gain control (AGC) circuit of the main amplifier which is connected to the latter stages of the preamplifier circuit for photoelectric conversion.

[0007] In the case of the preamplifier circuit for photoelectric conversion of FIG. 6, when the input signal current I is amplified and the output voltage V_{OUT} of the inverting amplifier circuit *2* increases, the gate voltage of the FET *4* is controlled by the AGC circuit *5* of the main amplifier of the latter stages, and a portion of the input signal current I is shunted to the FET *4* by virtue of the fact that the impedance between the drain (D) and the source (S) of the FET *4* is lowered, thereby preventing saturation of the inverting amplifier circuit *2*.

[0008]

[Problems to Be Solved by The Invention] However, in the case of the preamplifier circuit for photoelectric conversion of FIG. 6, since the FET *4* that shunts the input signal current I is controlled by the AGC circuit *5* of the main amplifier of the latter stages, there is the drawback that the response speed with respect to changes in the input signal is slow, making it difficult to operate stably up to a high transmission bit rate, while making it difficult to ensure a broad dynamic range.

[0009] The present invention was devised on the basis of the aforementioned situation, and has as its object to provide a preamplifier circuit for photoelectric conversion capable of high-speed response to changes in the input signal, and capable of operating stably up to a high transmission bit rate, while ensuring a broad dynamic range.

[0010]

[Means for Solving These Problems] The present invention is a preamplifier circuit for photoelectric conversion, formed from a photoelectric conversion element that converts an optical signal into an electric signal, and an inverting amplifier circuit connected to the input terminal and the output terminal, with the converted electric signal as an input signal, and characterized in that said inverting amplifier circuit in constructed in multiple stages, utilizing a plurality of inverting amplifiers, and a variable impedance element is connected to the input terminal and the output terminal of the inverting amplifier of the first stage of said inverting amplifier circuit constructed in multiple stages, and in addition, there is provided an impedance control means that controls the impedance of said variable impedance element in response to an output signal of the inverting amplifier of the first stage of said inverting amplifier circuit constructed in multiple stages, and when the input signal increases, the impedance of said variable impedance element is controlled so that it decreases.

[0011]

[Operation of the Invention] When the input signal to the inverting amplifier circuit increases, the impedance control means detects this from the changes in the output signal of the first stage inverting amplifier, and controls the impedance of the variable impedance element so that it decreases. Accordingly, a portion of the input signal that enters the negative feedback resistor is shunted to the impedance element side, thereby preventing saturation of the inverting amplifier circuit. Consequently, the duty ratio of the output pulse no longer changes due to saturation of the inverting amplifier circuit.

[0012] Moreover, the response speed with respect to changes in the input signal current is extremely high, and operation is stable up to a high transmission bit rate.

[0013]

[Examples] Examples of the present invention are described with reference to drawings. FIG. 1 depicts an example of a preamplifier circuit for photoelectric conversion of the present invention. In FIG. 1, ***1*** is a photodiode; ***2*** is a multistage inverting amplifier circuit formed from three inverting amplifier circuits $\boldsymbol{2_1}$ - $\boldsymbol{2_3}$; ***3*** is a negative feedback resistor that is connected to the input terminal and the output terminal of the inverting amplifier circuit ***2***; ***4***

is an N-channel MOS-type FET serving as a variable impedance element for shunting, and is connected to the input terminal and the output terminal of the first-stage inverting amplifier circuit ***2_1*** of the multistage inverting amplifier circuit; ***6*** is an impedance control amplifier. It should be noted that the parts that are the same as in the prior art circuit are indicated with the same reference numbers.

[0014] As shown in FIG. 1, the present invention preamplifier circuit for photoelectric conversion is designed in such a way that the impedance control amplifier ***6*** is connected to the output terminal of the first-stage inverting amplifier circuit ***2_1*** of the multistage inverting amplifier circuit, so as to control the gate voltage of the FET ***4*** by this impedance control amplifier ***6***.

[0015] The operation of the circuit of FIG. 1 is explained with reference to FIG. 2 and FIG. 3. It should be noted that FIG. 2 shows the input and output characteristics of the impedance control amplifier ***6***, and FIG. 3 shows the impedance characteristics of the FET ***4***.

[0016] The input signal current I is within a normal operating range that is under the saturation region, and the operating point of the impedance control amplifier ***6*** at this time is given by point ① in FIG. 2, and the corresponding operating point of the FET ***4*** is given by point ② in FIG. 3. Therefore, as shown in FIG. 3, the impedance Z between D and S of the FET ***4*** in this case has a large value on the order of 10 kΩ.

[0017] Now, as the input signal current I increases, and as the current flowing to the FET ***4*** increases, the potential of the input terminal A of the impedance control amplifier ***6*** changes as from point ① to point ② in FIG. 2, and the potential of the output terminal B increases. Accordingly, the operating point of the FET ***4*** changes as from point ① to point ② in FIG. 3, and the impedance Z between D and S of the FET ***4*** drops greatly, from 10 kΩ to 1 kΩ, as shown, for example, in FIG. 3.

[0018] As a result of this drop in impedance, there is an increase in the volume of the input signal current I shunted to the FET ***4***, and there is a decrease in the input signal current I flowing into the negative feedback resistor, and the output voltage V_{OUT} of the inverting amplifier circuit ***2*** is decreased by that amount, thereby preventing saturation of the inverting amplifier circuit ***2*** due to the increase in the input current signal I.

[0019] Therefore, the duty ratio of the output pulse no longer changes due to saturation of the inverting amplifier circuit ***2***. Moreover, since the impedance of the FET ***4*** is controlled using the output signal of the first-stage inverting amplifier circuit ***2_1*** of the multistage inverting amplifier circuit, the response speed with respect to changes in the input signal current is extremely high, and operation is stable up to a high transmission bit rate.

[0020] FIG. 4 shows an example of computed analytic results of output wave forms resulting from the aforementioned example. FIG. 4 shows the analysis of the output pulse wave form of the inverting amplifier *2* when a pulse signal of a transmission bit rate of 28.8 Mbps serves as an input signal, and when the measured value of the current of this input pulse fluctuates. FIG. 4 clearly demonstrates that even if the measured value of the current of the input pulse varies, the rising position and the falling position of the output pulse waveform are almost constant.

[0021] It should be noted that in the aforementioned example, if one sets the output voltage of the impedance control amplifier *6* lower than the gate threshold voltage V_{TH} of the FET *4* when the input signal current I is at the lowest receiving level, it is possible to set the FET *4* at a cut-off state (unlimited impedance) when the input signal current I is at the lowest receiving level, making it possible to eliminate the effect of the thermal noise of the FET *4* when at the lowest receiving level, and making it possible to reduce the input scale noise by that amount when at the lowest receiving level.

[0022] Furthermore, in the aforementioned example, an N-channel MOS-type FET serving as a variable impedance element was used, but the present invention is not limited thereto, and of course, a P channel MOS-type FET can be used, as well as a bipolar transistor or other semiconductor element can be used as a variable impedance element.

[0023]

[Advantageous Effects of the Invention] It is clear from the above discussion that when the present invention preamplifier circuit for photoelectric conversion is used, an inverting amplifier circuit is constructed, utilizing a plurality of inverting amplifiers, with a variable impedance element connected to the input terminal and the output terminal of the inverting amplifier of the first stage of said multistage inverting amplifier circuit, and there is also provided an impedance control means that controls the impedance of said variable impedance element in response to an output signal of the inverting amplifier of the first stage of said inverting amplifier circuit constructed in multiple stages, and when the input signal increases, the impedance of said variable impedance element is controlled so that it decreases, with the result that there is much greater speed of response to changes in the input signal, making it possible to operate stably up to a high transmission bit rate, while ensuring a broad dynamic range.

[0024] Moreover, since the impedance of the aforementioned variable impedance element is set so that it is infinitely great at the lowest receiving level for the input signal, it is possible

to eliminate the effects of thermal noise of the variable impedance element when at the lowest receiving level, making it possible to reduce the input scale noise when at the lowest receiving level.

[Brief Description of the Drawings]

[FIG. 1] A circuit diagram of a present invention preamplifier circuit for photoelectric conversion.

[FIG. 2] A graph showing an example of the input and output characteristics of the impedance control amplifier in FIG. 1.

[FIG. 3] A graph showing an example of the impedance characteristics of the FET in FIG. 1.

[FIG. 4] A wave form analysis graph of pulse signal output generated by computer for the circuit of the present invention.

[FIG. 5] A circuit diagram showing the first example of a prior art preamplifier circuit for photoelectric conversion.

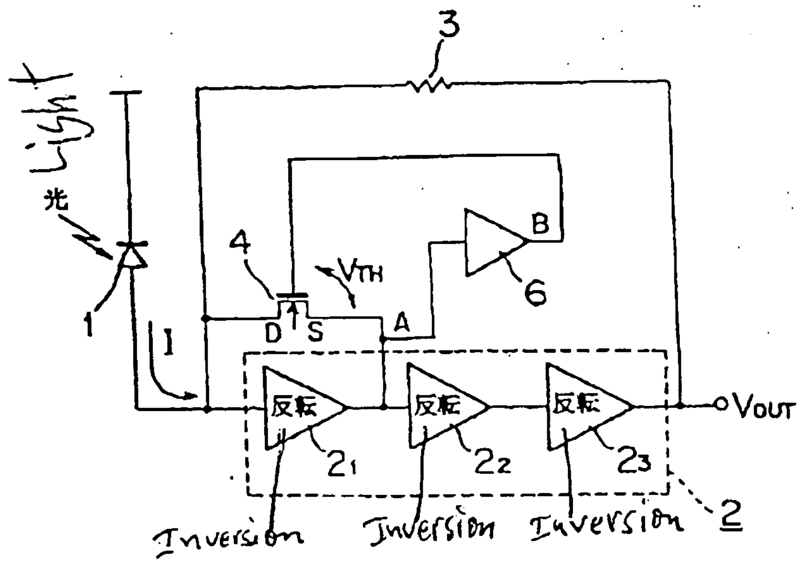
[FIG. 6] A circuit diagram showing the second example of a prior art preamplifier circuit for photoelectric conversion.

[Explanation of the Reference Numbers]

1 Photodiode (photoelectric conversion element)
2 Inverting amplifier circuit
2_1 - 2_3 Inverting amplifiers
3 Negative feedback resistor
4 FET (impedance variation element)
6 Impedance control amplifier (impedance control means)

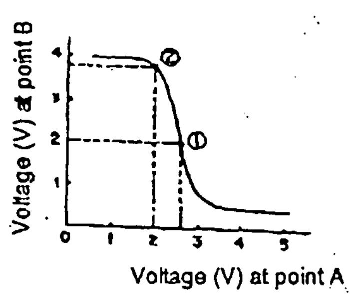
[FIG. 1]

Example



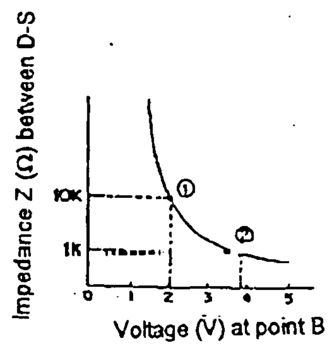
[FIG. 2]

Input and output characteristics of the impedance control amplifier in FIG. 1



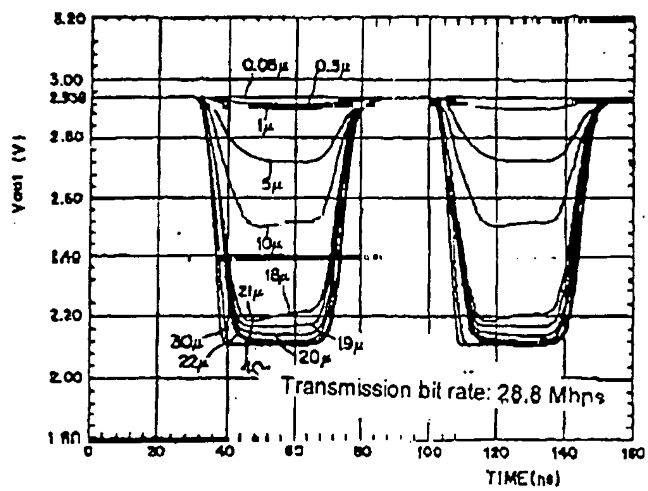
[FIG. 3]

Impedance characteristics of the FET



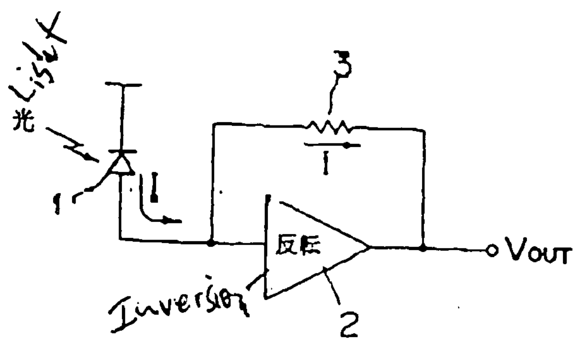
[FIG. 4]

A wave form analysis graph of pulse signal output generated by computer for the circuit of the present invention



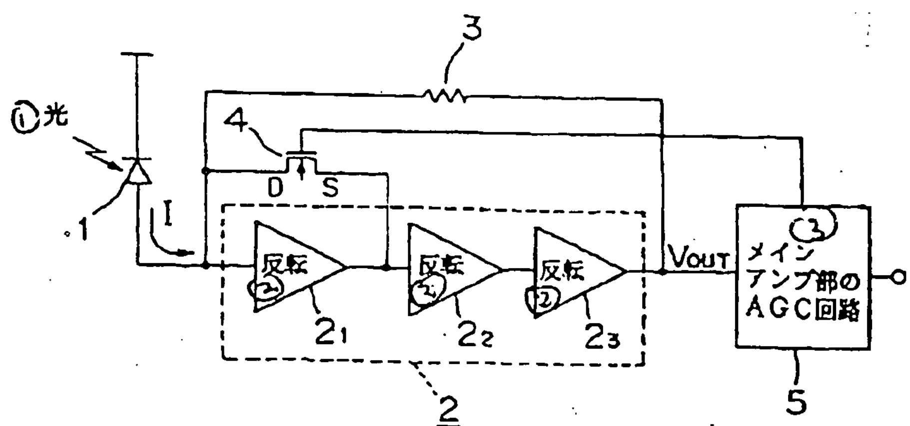
[FIG. 5]

The first example of a prior art preamplifier circuit for photoelectric conversion



[FIG. 6]

The second example of a prior art preamplifier circuit for photoelectric conversion



Key:

(1) Light
(2) Inversion
(3) AGC circuit of
the main amplifier part

Translated by John F. Bukacek (773/508-0352)